UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

BERKELEY, CALIFORNIA

THE SELECTIVE IMPROVEMENT OF THE LIMA BEAN

BY

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BULLETIN No. 238

Berkeley, Cal., May, 1913

BERKELEY

THE UNIVERSITY OF CALIFORNIA PRESS

1913

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THE SELECTIVE IMPROVEMENT OF THE LIMA BEAN*

BY

G. W. SHAW

SUMMARY

1. During four years the increase in yield of selected strains over common stock was about 20 per cent.

2. U. C. Stock No. 1 (Daily type) has yielded over 25 per cent higher than common stock.

3. The average increase in yield of six select strains of three different types was 24.3 per cent in 1911 and 14.4 per cent in 1912.

4. Among fifty select strains developed from individual plants and tested with check areas of common stock in 1912, sixteen gave 20 per cent or higher increase in yield, eleven gave 30 per cent or higher increase, seven gave 40 per cent or higher increase, and three gave 50 per cent or higher, one of the three giving 121.8, and the other 160 per cent increase. The possibility of developing high yielding strains from such selections and the value of testing the offspring of each plant separately is obvious.

5. Farmers can increase their yield and improve the quality of the crop simply by seed selection and better by plant selection in the field, growing the seed from selected plants in a special plat and repeating this plant selection year after year.

6. The Lima bean as grown in California, requires improvement for earliness, hardiness, alkali resistance, quality and yield. There is definite possibility of improvement in all these respects, especially if the individual plant is made the unit of selection and the progeny of each plant is tested separately.

* The writer desires to express the thanks of the Station, as well as his personal appreciation of the hearty coöperation rendered by the Lima Bean Grower's Association, who have assisted financially and otherwise in the prosecution of this work; and also to acknowledge the many courtesies and assistance extended by Messrs. F. A. Snyder and W. E. Goodyear, of Somis, and by the Patterson Ranch Co., and Donlan Brothers of Oxnard, who have furnished land, labor and teams as needed for planting, cultivating and harvesting the several crops. Credit should also be given to Messrs. V. C. Bryant, B. A. Madson, and J. A. Denny, who in various ways, have assisted in conducting the details of the field operations.

During the past few years there has been a great awakening upon the subject of the selective improvement of farm crops, and marked results have been obtained by the selection and breeding of better types of corn, tobacco, cotton, and cereal crops. The improvement of general farm crops has not advanced as far in this direction as in the case of horticultural crops, because the necessity of such improvement has not been so apparent, but with the increasing price of land and with greater attention being given to specialized and intensive farming, such improvement of crops is now becoming of as great interest in the case of fruit, flowers, and live stock.

For several years the Agricultural Experiment Station of the University has conducted experiments in developing more uniform and higher yielding types of lima beans than those now used by growers of this product. The results of these experiments have been most encouraging. In brief it may be said that the increased yields obtained from tests made with the selected strains have been as follows:

1909	16.95 per cent
1910	23.92 per cent
1911	24.30 per cent
1912	14.40 per cent
Average	19.89 per cent

THE PLAN OF IMPROVEMENT AS UNDERTAKEN

The experiments here recorded were begun by the writer in 1908 in coöperation with a number of Ventura county farmers, and although at the outset it was intended to include selections for earliness as well as yield, on account of the impossibility of having a qualified man on the ground during the entire ripening period the experiments were finally reduced to the standpoint of yield only.

In the fall of 1908 about 10,000 individual plants which showed from a cursory examination, desirable characteristics were staked in the field. At the time of the first selection in July, earliness of blooming stood almost alone in influencing the marking of plants, except that some attention was given to size and vigor of vine where this did not appear to be due to a difference in growing space, and hence, in amount of plant food available. Vigorous and thrifty plants, which appeared to be so because of inherent character, were selected, and in no case were small, stunted plants chosen. The plants were pulled, care being taken to separate the vines from those of surrounding plants, and each was inspected quickly after turning it over, so that the pods

were easily seen. If the pods were found to be immature, or if the total number of pods was small, the plant was dropped, except that some plants with a small number of pods were carried along if the plant was very mature, and some very high yielding plants were kept, though immature. In this way, about three thousand plants were selected out of the original ten thousand.

After a short period of drying, the pods were picked from each plant and placed in a paper bag. The bags were numbered consecutively, corresponding to cards on which data regarding the number of dry pods, the number of pods to be shelled, and number of pods too immature to shell, and length of the vine, were recorded. Two numbers were then arbitrarily chosen for the plants from each field, one representing number of dry pods, the other representing total number of pods, and those plants which did not exceed either of these numbers were discarded. About fifteen hundred of the more immature and light yielding plants were discarded in this way. The pods from all the remaining plants were shelled, keeping the lot from each plant separate from all the others. Finally, all but about six hundred from the original ten thousand wer discarded before planting in the spring of 1909. The seed from these six hundred plants were grown in rows as foundation stock in 1909, the seed from each plant being planted separately, so that the yield, and other desirable characters of their product, might be determined.

DO HIGH-YIELDING PLANTS PRODUCE HIGH-YIELDING OFFSPRING?

The fact that certain selected plants produced yields is no evidence that they will transmit this characteristic to their progeny. This can only be told by field trials conducted in such a manner as to enable the performance record of these plants to be studied over a series of years. Some plants may themselves be productive, but lack projective efficiency in the desired direction. This prepotency of the parent plant must first be determined before one can be assured that the plant is a desirable one to increase. *Prepotency in a desired direction is just as important in plants as in animals.*

The projective efficiency of the plants from the foundation stock was determined by means of the plant-to-row method, in which trials one row is planted from the beans of each of the selected plants, an accurate record of the yield of each of the rows, being kept. Such trials have been made each year since 1908, both at Somis and at Oxnard. In the seasons of 1911 and 1912 the most promising strains were increased for field plantings. Two of the strains were seeded on

the ranch of Mr. F. A. Snyder at Somis, in the ordinary manner, against check areas of common stock for comparison. The results were as follows:

	Yield per acre; selection	Pounds common stock
U. C. Stock No. 1 (Daily type)	1851.5	1476.5
U. C. Stock No. 2 (Lewis type)	1598.0	1497.9
Increase of selected over common seed	375.0	101.0
Per cent increase	25.4	6.7

From the planting of 1911[1] fifty were deemed worthy of further trial in 1912, seventeen of which were grown at Somis the preceding season. These fifty strains were planted on plots of approximately one-twentieth of an acre, in competition test, on the Patterson ranch at Oxnard in 1912. The results of this test are recorded below:

TABLE SHOWING PERFORMANCE RECORD OF SELECTED STRAINS OF LIMA BEANS IN PLATS AT OXNARD, 1912

		Plat Plantings			
		1912 Yields in pounds			
Plat No. 1912	Row No. 1911 Parent No. 1912	Yield per acre pounds	Check yield per acre corrected	Gain or loss* in yield, pounds per acre	Per cent gain
1	2	1712	2250	*538*	.....
2	3	2446	2250	196	8.7
CI L	Check	*2250*	2250	.....	.....
3	6	2260	2071	189	9.1
4	8	1620	1892	*270*	.....
5	9	1872	1713	159	9.2
6	10	1870	1534	336	21.2
CII L	Check	*1354*	1354	.....	.....
7	11	1740	1418	322	22.7
8	15	3860	1481	2379	160.0
9	16	3420	1544	1876	121.8
10	17	2420	1607	813	50.8
CIII L	Check	*1670*	1670	.....	.....
....	20	1900	1786	114	6.4
12	22	1546	1902	*356*	.....
13	27	1944	2018	*74*	.....
14	29	2226	2134	92	4.3
CIV L	Check	*2250*	2250	.....	.....
15	30	2700	2249	451	20.1
16	32	2610	2248	362	16.1
17	35	2902	2247	655	29.2
18	40	2460	2246	214	9.5

[1] For results of previous years see Bull. 224, Agr. Exp. Station, Berkeley, Cal.

* Loss indicated by italics.

PLAT PLANTINGS

Plat No. 1912	Row No. 1911 Parent No. 1912	1912 Yields in pounds: Yield per acre pounds	1912 Yields in pounds: Check yield per acre corrected	Gain or loss* in yield, pounds per acre	Per cent gain
CV L	Check	*2244*	2244	.....	.....
19	41	2442	2134	308	14.4
20	42	2042	2027	15	0.7
21	45	2522	1920	602	31.4
22	49	2666	1813	853	47.1
CVI L	Check	*1706*	1706	.....	.....
23	50	2350	1769	581	33.0
24	53	2010	1832	178	9.7
25	55	2754	1895	859	45.4
26	61	2714	1958	756	38.7
CVII L	Check	*2022*	2022	.....	.....
27	62	2222	2002	220	11.0
28	66	2464	1984	480	24.2
29	67	2068	1966	102	5.2
30	70	1588	1948	*360*	.....
CVIII L	Check	*1930*	1930	.....	.....
31	72	2810	1967	843	43.0
32	73	2080	2004	76	3.8
33	74	2760	2041	719	35.2
34	39	2222	2078	144	7.2
CIX Kos	Check	2114	2114	.....	.....
35	41	2364	2203	161	7.3
36	44	2244	2292	*48*	.....
37	17	2710	2381	329	13.7
38	19	3654	2470	1184	47.9
CX D	Check	*2560*	2560	.....	.....
39	20	2320	2500	*180*	.....
40	22	2460	2440	20	0.8
41	25	1720	2380	*660*	.....
42	2	1980	2320	*340*	.....
CXI D	Check	*2260*	2260	.....	.....
43	4	2260	2192	68	3.1
44	8	2188	2124	64	3.0
45	9	2236	2056	180	9.0
46	14	2000	1988	12	0.6
CXII D	Check	*1920*	1920	.....	.....
47	26	1820	1854	*34*	.....
48	28	1520	1788	*268*	.....
CXIII Kos	Check	*1720*	1720	.....	.....
49	31	1960	1720	240	13.9
50	33	1768	1720	48	2.7

Average yield 50 new sorts ..... 2288.5 lbs. per acre
Average yield checks ..... 2000 lbs. per acre
Actual average increase ..... 288.5 lbs. per acre
Per cent average increase ..... 14.4 lbs. per acre

* Loss indicated by italics.

Note 1.—In the above and preceding tables the column headed "corrected check yield" needs some explanation. The comparison of two rows or plats grown side by side may not be a fair estimate upon which to base conclusions since the land frequently changes within short distances. It is desirable to determine as nearly as possible what the check seed would have yielded if sown on the same row or plat as the plant being checked. Consequently, a correction is introduced in aiming to allow for such soil differences. The amount to add or subtract as the case may be, to the yield of the check in each case, is determined by finding the difference between the yield from the selected plant and the check, and divide this number by the number of rows between the checks. In these trials every fifth row was a check row seeded with common stock seed. Now if as in Plat No 3, 1912, check plat I yielded 2250 pounds per acre, and the next check CII gave 1354 lbs. per acre, it is probable that the land was poorer as we proceed from CI towards CII. The difference between the two check plats is 896 pounds. In every five plats there is one check and one-fifth of 896 lbs. is 179 lbs. Now if we subtract 179 lbs. from the yield of plat CI we get the *corrected yield* for plat 3 which is 2071 lbs. Subtracting 179 lbs. from this gives 1892 lbs. the corrected check for plat 4 etc. If there is an increase between the two check plats, the correction is obtained in a similar manner by addition. It is evident that between any two check plats the correction will usually be a different number.

Note 2.—(The probable high value of a strain of seed that might be developed from a single plant whose progeny produces high relative yield should not be overlooked. In the above table there are five plats whose yields are respectively 47.1, 47.9, 50.8, 121.8 and 160 per cent higher than the corrected check yield of common stock seed. The plants in each plat were the offspring of a single ancestor, assuming that lima bean flowers are self-fertile like the flowers of other beans. Thus each plat is a "pure line" and by saving the seed of each plat separately each pure line is preserved as a distinct strain until there is enough seed to test it under field conditions. Theoretically further selection within the pure line is useless, so that if the strains tested fail to produce satisfactorily in average years under average conditions, it would be necessary to repeat the selection of individual plants in the field and subsequent testing of the same. The importance of testing the progeny of each selected plant separately cannot be over-emphasized. However, the writer does not wish to assert at this time, that selection within the pure line is absolutely without effect.—Ed.)

Trials of six other strains, also grown at Somis in 1911, were made on the Donlon ranch at Oxnard in 1912. These strains were planted in one-acre plats. The results are given in the following table:

TABLE SHOWING PERFORMANCE RECORD OF SELECTED STRAINS OF LIMA BEANS, SOMIS 1911 AND OXNARD 1912

Plat number	Type	Pounds per plat One twenty-fifth: Selection	Pounds per plat One twenty-fifth: Corrected check	Pounds per acre: Selection	Pounds per acre: Corrected check	Pounds increase	Pounds per acre Acre plats: Selection	Pounds per acre Acre plats: Check	Pounds increase
13	Lewis	97.0	85.5	2425.0	2147.5	287.5	3055.5	2133	822.5
12	Lewis	105.0	80.6	2637.5	2015.0	622.0	2318.0	2604	286.0
9	Daily	840.0	75.8	2100.0	1895.0	205.0	3134.0	2143	1101.0
8	Daily	80.5	72.5	2012.5	1812.5	200.0	2964.0	2784	180.0
10	Daily	90.0	77.0	2250.0	1925.0	225.0	3140.0	2744	356.0
28	King of the Garden	112.0	80.5	2800.0	2012.5	787.5	2960.0	2387	573.0
Average yield, 6 new sorts.				2370.8	1966.2	464.4	2928.6	2471	497.6
Average increase				464.4	.....	.....	467.6	.....	.....
Per cent increase				24.3	.....	.....	14.4	.....	.....

Present Method of Seed Selection.—Seed selection is, at present, practiced to some extent, but no such method as will do much toward maintaining a definite, uniform type is in use. The method used is that of hand picking for seed purposes, and amounts only to a good recleaning with elimination of the "poppers," a well defined and undesirable bean of the small, flat class of limas.

The practice of hand picking is good just so far as it affects the quality of the seed. By hand picking a very large portion of the "poppers" are removed, and any seed of the large, flat class of limas which may be very small because unripe at harvest, and hence likely to make weak growth if planted, will also be removed, together with all decayed or moldy beans. This insures, as far as strong seed can, a good germination and an even stand in the field the following season with a limited number of "poppers." It is a practice which is conducive to higher yields per acre from the seed used, but makes no pretension of permanently improving the seed.

A Better Method of Selection.—A better method of seed selection than the one now commonly practiced would be in addition to that outlined above, the selection of individual plants in the field. This can be done at small cost, just before harvest of the general crop. The old method of harvesting, that of pulling the plants, will have to be used, and, furthermore, the plants must be carried out of the field to be piled, in order that the selections shall not be in the way of the cutters at the harvest of the main crop. However, by taking the beans

required for seed from near the sides of the field, one will avoid carrying the plants long distances. Before threshing, the machine should be cleaned of any morning-glory or other weed seed which it might have, thus preventing, in large measure, the spreading of these pests from infected to uninfected fields.

This selection in the field would insure freedom of the seed from admixture of "poppers," while hand picking would add its benefit by eliminating any small or moldy seed. Uniformity of plant and of seed in all characters can also be obtained, giving a product such as the best markets demand, and for which the highest prices are paid.

The grower himself can do much more than he is now doing toward improving his yield by seed selection. A practical method of seed improvement, which should be followed by every bean grower in California, is the maintenance of a seed plat. The method is simple and easily applied. First, select from the general field, at the time of crop maturity, a large number of plants that are manifestly heavily laden with ripe pods, choosing, so far as possible, those plants bearing a high average of beans to the pod. These plants should not be taken from spots where the stand is poor, nor from outside rows, nor from parts of the land which are unusually fertile, but should rather represent those grown upon the general soil condition. These selected plants should be removed from the field and threshed separately from the general crop. The seed, so selected, should be used upon a special seed plat the succeeding season, and the seed from this seed plat used in the second season for the general seeding. This selection could be carried still further by choosing the very best plants from the seed plat to be increased in the second season for subsequent use upon the seed plat, and thus introduce a little more vigorous selection. In order to perpetuate the good results, the grower should practice such selection every year. (See note 2, p 0). More elaborate plans of selection could be worked out, but the general grower usually has not the time at his disposal to undertake more elaborate schemes. The above plan, however, is so simple that there is no apparent reason why it should not be quite universally applied to this as well as other crops with much advantage to the grower and the community.

DESIRABLE IMPROVEMENT

Earliness.—It is the general practice to cut many fields before the plants are fully matured and before the beans have reached their full size. This indicates the need of an earlier-maturing bean, which will lessen the danger of loss from early fall rains. Such early rains always mean serious loss and inconvenience to the grower.

Hardiness.—There is often a marked lowering of the yield, the amount of which can only be conjectured, due to stunting of plants by cold east winds in May. These winds sometimes blast certain fields badly. Very strong east winds in the fall hasten the drying of the beans that are cut, but have been known to sweep the whole crop from the field. An earlier bean would escape the cold winds in May, also the strong winds and the rain of September.

However, there are certain plants which, although apparently exposed to exactly the same conditions as their fellows, are not injured so much, or even not at all. By taking seed from these seemingly resistant individuals, we should expect to produce, after several generations, a strain capable of enduring and growing under colder atmospheric conditions than the original or parent type. (See note 2, p. 586.) Moreover, lengthening the season of growth at its beginning might allow of earlier ripening and harvest—a distinct advantage.

Alkali Resistance.—Selecting in like manner those plants which appear resistant to alkali might give a strain better suited to alkali soils than any varieties now grown. Such a strain would cause an increase in the acreage of limas in Ventura County.

Quality.—Another desirable improvement could be made in quality of shelled-beans. This is, at present, especially desirable to the buyers, but would result also in profit to the growers. By quality is meant, not beans with a better flavor or more easily cooked, but beans which are uniform in size, shape, color and markings. Certain markets will not take the average quality of the product, but require the finest looking and most uniform lots that can be obtained. This necessitates grading of the beans. The culls go to the less discriminating markets mixed with other ungraded lots, and are sold at a smaller price than choice beans. Although, at present, a flat rate is paid the growers, the buyers and shippers grading the beans and shipping according to market demands, this flat rate might be increased or a sliding scale established to the benefit of the enterprising growers if a uniform type of bean could be furnished. This would not be possible with the present late maturity, as the small, immature bean would always have to be graded out, but might be possible with the establishment of an early maturing strain. In any case, the odd and angular-shaped beans should be eliminated, and this can doubtless be done by paying more attention to seed selection, rejecting seed from those plants showing a tendency to angularity.

Yield.—Another very desirable improvement is that of yield. Grant all other improvements, then, without high yield the grower does not want the plant. And the grower's position is indisputable. High

yield is of first importance. In observing the plants in the field, vast differences can be seen in the yield of individuals. However, it should be observed that the heaviest yielding plants are usually late maturing, and that the early maturing plants are light yielders,—hence one cannot bear too heavily on the matter of earliness without, in a measure at least, reducing the yield. However with plants of a less vining tendency somewhat thicker planting can be practiced, and this deficiency somewhat offset by the larger number of producing plants.

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227. Grape Vinegar.
230. Enological Investigations.
232. Commercial Fertilizers.
233. Three Years' Work of the Ferndale (Humboldt County) Cow Testing Association.
234. Red Spiders and Mites of Citrus Trees.
235. Further Proof of the Cause and Infectiousness of Crown Gall.
236. The Economic Value of the Western Meadowlark in California.
237. Pork Production under California Conditions.

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No. 1. Texas Fever.
9. Asparagus Rust.
29. Preliminary Announcement Concerning Instruction in Practical Agriculture upon the University Farm, Davis, Cal.
46. Suggestions for Garden Work in California Schools.
52. Information for Students Concerning the College of Agriculture.
55. Farmers' Institute and University Extension in Agriculture.
60. Butter Scoring Contest, 1910.
61. University Farm School.
62. The School Garden in the Course of Study.
63. How to Make an Observation Hive.
65. The California Insecticide Law.
66. Insecticides and Insect Control.
67. Development of Secondary School of Agriculture in California.
68. The Prevention of Hog Cholera.
69. The Extermination of Morning-Glory.
70. Observation of the Status of Corn Growing in California.
74. Rice.
75. A New Leakage Gauge.
76. Hot Room Callusing.
77. University Farm School.
No. 78. Announcement of Farmers' Short Courses for 1912.
79. List of Insecticide Dealers.
80. Boys' and Girls' Clubs.
81. Sweet Pea Growing Clubs.
82. The Common Ground Squirrels of California.
83. Potato Growing Clubs.
84. Mushrooms and Toadstools.
85. A Preliminary Report of a Nematode Observed on Citrus Roots and its Possible Relation with the Mottled Appearance of Citrus Trees.
86. Olives in California.
87. Alfalfa.
88. Advantages to the Breeder in Testing his Pure-bred Cows for the Register of Merit.
89. Hog Cholera and its Prevention.
90. Tuberculosis in Cattle and Hogs.
91. Disinfection on the Farm.
92. Infectious Abortion and Sterility in Cows.
93. Bean Growing Clubs.
94. The Dairyman's Relation to Quality.
95. Detecting Dairy Losses.
96. Pork Production.
97. Increasing Dairy Profits.
98. Plowing and Cultivating Soils in California.
99. Hatching and Rearing of Chicks.